A Scheme of Optimal Channel Selection with Channel Evaluation for WSNs

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Abstract

The frequency hopping technology is widely used in wireless sensor networks with the security becomes more and more important. Channel evaluation is important for adaptive frequency hopping system and we proposed a scheme of optimal channel selection with channel evaluation, which can get an accurate and comprehensive channel evaluation by analyzing the Signal-To-Noise Ratio (SNR), loss rate and delay.

Keywords: *frequency hopping, channel evaluation, optimal channel selection*

1. Introduction

With the rapid development of wireless communication technology, the application of wireless sensor networks becomes more and more widely [1]. However, there may be many wireless devices working together in a small space, causing interference and congestion problems for wireless sensor networks [2]. Hopping communication is a good way to solve this problem. When the communication is blocked in a channel, it can transform to a new channel that has no interference to communicate. Ben Proposed SAFH [3] - Smooth Adaptive Frequency Hopping; Chang Liang proposed a new algorithm of SNR estimation based on subspace decomposition [4]. This algorithm can avoid estimating the spatial dimension of signal and noise by making a particular auto-correlation matrix. Yong Jiang proposed a set of comprehensive network transmission control standards [5]. The standard puts forward the influence of packet loss rate, delay and throughput on the channel. Shio Kumar Singh [6] proposed a new approach of an Intrusion Detection Based Security Solution for Cluster-Based Wireless Sensor Networks. Methodology. In the proposed methodology, an efficient MAC address based intruder tracking system has been developed for early intruder detection and its prevention. Kalpana Sharma [7] analysed the various available security approaches highlighting their advantages and weaknesses. Dongwon Jeong [8] proposes a novel secure query processing model for semantic sensor networks. There is no effective hopping scheme to make hopping frequency sets quite confidential and random and to ensure that the selected channel is the optimal channel. In this article, we do some researches on the optimal channel selection and proposed the scheme of channel evaluation.

There is no effective hopping scheme to make hopping frequency sets quite confidential and random and to ensure that the selected channel is the optimal channel. The optimal channel is the channel that has no interference or at least without interference in a considerable period of time after skipping. In this article, we do some researches on the optimal channel selection and proposed the scheme of channel evaluation and the optimal channel selection.

2. The Framework of Proposed Scheme

In this paper, the main idea is adaptive frequency hopping. The so-called adaptive frequency hopping is to refuse to use those frequency points which were centralized frequency points among skipping frequency points and once used but with unsuccessful transmission, so that the communication can continue in a non-interfering frequency point, thereby, greatly improving the quality of the received signal in the frequency hopping communication system [9].At the same time, it can improve the concealment of the system as well.

Adaptive frequency hopping communication system needs to select the optimum channel according to the channel evaluation to perform frequency hopping, or to change the corresponding transmission parameters at the next time. Therefore, it is the first need to evaluate the quality of the channel. The SNR of the channel and the bit error rate are two parameters that are always used to characterize the quality of channel. In AWGN channel, the SNR determines the probability of error for each modulation scheme. The corresponding threshold value can be set from a given probability of error, as changing the respective transmission parameters. In wireless communication [10], many algorithms recognize SNR as a channel performance indicator; On the contrary, in digital communication, bit error rate is often used to reflect the quality of the communication channel. So the error rate is also an important parameter to evaluate the channel quality.

We do research mainly on two aspects. One is how to make an accurate and reasonable channel evaluation. Channel evaluation is very important because the accuracy of channel evaluation has influence on the accuracy of the channel prediction directly. Therefore, channel evaluation affects the accuracy of the optimal channel selection, and has influence on the next frequency hopping directly; the other one is how to make the system change to the optimal channel after frequency hopping.

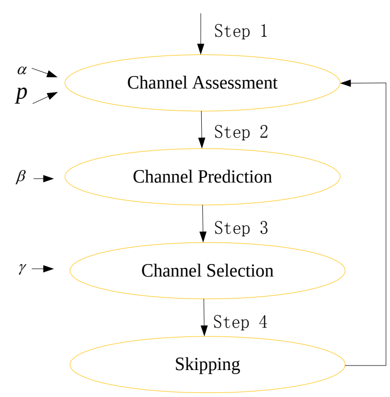

Figure 1. Block Diagram

Figure 1 is a simple schematic of the hopping process. It is divided into four steps. The first step is the channel evaluation; the second step is the channel prediction on the basis of channel evaluation for the next skipping; the third step is the selection of the optimal channel according to the results of the channel evaluation and channel prediction. The last step is skipping.

3. Channel Evaluation

Channel evaluation is an important technology for adaptive frequency hopping communication system. The result of current evaluation is the basis of the optimal channel selection, and also provides the basis of adaptive frequency control [11]. Generally, two methods are used in the channel evaluation: one is based on the bit error rate, the other is based on the SNR. The former is generally used in slow frequency hopping communication system, the error rate is estimated by the error detection coding and statistical.SNR is also one of the important indicators to evaluate channel quality. It can be used as an effective basis of adaptive control. To react to the channel changes in advance, highlighting the timely performance of adaptive control system, this paper introduced a channel quality evaluation method which is based on the SNR, while making reference to the transmission delay and loss rate, so that the results of channel evaluation are more accurate and more reasonable and can also meet the quality requirements of most applications at the same time.

3.1. The Evaluation of SNR

SNR is an important parameter of the communication signal, and it is also an important indicator of the quality of the wireless communication system, a lot of the wireless communication systems need to know the values of the SNR, in order to obtain the best performance of the channel. So, the SNR becomes an important issue for the wireless communication.

There are many ways to estimate the SNR of the wireless communication system, but most of them need to have a precise understanding of the various parameters of the received signal and rely much on priori knowledge, so they are complex to use. The SNR estimation method that based on signal autocorrelation matrix singular value decomposition does not depend on the priori knowledge of the signal. This algorithm is simple, and it can get a high estimation accuracy for different modulation signals. From the [12, 13], we can know the SNR of received signal can be calculated by the following formula

$$Z = 10\lg(P_s / P_n) = 10\lg\frac{\sum_{k=1}^{P}(\lambda_k - \sigma_n^2)}{M \times \sigma_n^2} \tag{1}$$

The signal power Ps can be expressed for each singular value, the noise power Pn is σ_n^2 times of that of *M*. The autocorrelation matrix of the received signal becomes $R_{rr} = V\Lambda_r V^H$ through singular value decomposition (*SVD*), λ_k is the element of $\Lambda_r = diag(\lambda_1, \lambda_2, \cdots, \lambda_M)_{M\times M}$, $diag(\square)$ is the matrix which regards • as the diagonal elements.

3.2. The Evaluation of Loss Rate and Delay

Now, We assumed that the distributions of the grouping length of all the services are same and the server continues to work, λ_k is the average arrival rate of the service *k*, $\overline{d}_k$ is the average queuing delay of the service *k*, λ is the representative of the average arrival rate of the overall system, then, the average delay that the service *k* is for the system is as follows [14]:

$$\overline{d}[\lambda] = \frac{1}{\lambda}\sum_{k=1}^{N}\lambda_k \overline{d}_k \tag{2}$$

Where

$$\lambda = \sum_{k=1}^{N} \lambda_k \tag{3}$$

The evaluation of loss rate of the system is very similar to the above delay formula. We assumed that the distributions of the grouping length of all the services are same and the server continues to work, τ_k is the grouping loss rate of the service k, then the total average loss rate of the system is as follows:

$$\tau[\lambda] = \frac{1}{\lambda} \sum_{k=1}^{N} \lambda_k \tau_k \tag{4}$$

3.3. Channel Synthesis Evaluation

About channel evaluation, we adopt the idea that combines the statistical average based on the historical category and based on the current category [15], as follows:

$$q_m = average \times \alpha + evaluation \times (1-\alpha) \tag{5}$$

m is the types of the parameters of channel evaluation, q_m is the evaluation value of the parameter m, α is the proportion of the average of the parameter based on the statistical idea in the total valuation of this parameter. $(1-\alpha)$ is the proportion of the current evaluation of the parameter based on the total valuation of this parameter. α changes from 0 to 1. The greater α is, the greater impact on the total evaluation value of the parameter based on historical factors is, while the impact of the evaluation value based on current factors decreasing. Or it will verse. However, there are many parameters (such as loss rate, delay, etc.) in channel. The impacts of different parameters on the composite index of the channel are different. Each parameter has its own proportion in the composite index of the channel evaluation value,

$$Q_i = \sum_{m=0}^{m=N} q_m' \times p_m \tag{6}$$

Q_i is the comprehensive evaluation index of the channel i. q_m' is the effective assessed value of parameter m of each channel. pm is the proportion of the parameter m in the comprehensive evaluation index of the channel i. Each channel has its comprehensive evaluation index. The channel whose comprehensive evaluation index is highest is considered as optimal channel. In this paper, we use three parameters that are SNR, channel transmission delay and channel loss rate to reflect the quality of the channel, so N is equal to 2, and i=0, i=1, i=2 represent SNR, the transmission delay and loss rate, so:

$$Q_i(t) = p_0 q_0'(t) + p_1 q_1'(t) + p_2 q_2'(t) \tag{7}$$

where

$$p_1 + p_2 + p_3 = 1 \tag{8}$$

q_0', q_1', q_2' respectively represent the effective evaluated value of SNR, delay and loss rate, p_0, p_1, p_2 are the proportion of each parameter in the comprehensive evaluation value. $\bar{Z}(t), \bar{\bar{d}}(t), \bar{\tau}(t)$ are the average values of SNR, delay and loss rate at the moment of t. $Z(t), \bar{d}(t), \tau(t)$ are the current evaluation values of SNR, delay and loss rate at the moment of t.

As we all know, if the value of the SNR increases, the value of channel quality increases as well, so:

$$q_0'(t) = \bar{Z}(t)\alpha + Z(t)(1-\alpha) \tag{9}$$

On the contrary, if the value of the delay and the loss rate increase, the value of channel quality decreases. So $q_1'(t)$、$q_2'(t)$ are as formulas (10) and (11) through Once-order fit measurement:

$$q_1'(t) = k\frac{1}{\left[\bar{\bar{d}}(t)\alpha + \bar{d}(t)(1-\alpha)\right]} + b \tag{10}$$

$$q_2'(t) = m\frac{1}{\left[\bar{\tau}(t)\alpha + \tau(t)(1-\alpha)\right]} + n \tag{11}$$

$Q_i(t)$ can be obtained by putting (9), (10), (11) into (7)

4. Channel Prediction

In the second step the channel prediction, the exponential smoothing method is used to predict the channel quality respectively in the next moment, (Q_i , $\forall i \in \{1 \cdots N\}$) [16]. It is written as follows.

$$\begin{cases} Q_i'(t+1) = \beta Q_i(t) + (1-\beta)Q_i'(t) \\ Q_i'(1) = Q_i(0) \end{cases} \tag{12}$$

The channel quality at the moment of *t+1* is predicted by the evaluation value at the moment of *t* and the predicted value at the moment of *t*. $Q_i(t)$ is the comprehensive evaluation index of the channel i at the moment of *t*, $Q_i'(t)$ is the prediction value of the channel *i* at the moment of *t*. β is the proportion of the comprehensive evaluation index at the moment of *t* in the prediction value of the channel in the next moment. 1-β is the proportion of the prediction evaluation at the moment of t in the prediction value in the next moment. β is smoothly change from 0 to 1. β controls the balance between the old data and the new data. With the value being closer to 0, the impact of the present evaluation of channel on the prediction of the next moment reduces.

5. The Selection of Optimal Channel

We know that if the result of a channel evaluation is better and the result of the channel prediction is better as well, then it is more close to the optimal channel. So, each channel needs to have its own weight in optimal channel selection. Channel quality has proportional relationship with its own weight, so:

$$f(t+1) = f_0 + \sum_{i=0}^{n} f_i \times weight \tag{13}$$

$f(t+1)$ is the frequency value of the optimal channel that the system will jump to in the next moment, f_0 is the lowest communication frequency value, the weight of each channel has the relationship with and the current channel evaluation and the channel prediction, so:

$$weight=\varphi[Q_i(t)]\gamma+\varphi[Q_i'(t+1)](1-\gamma)\eta \tag{14}$$

$\varphi[Q_i(t)]$ is a function about the channel evaluation. $\varphi[Q_i(t+1)]$ is a function about the channel prediction. γ is the proportion of the channel evaluation in the channel weight. $1-\gamma$ is the proportion of the channel prediction in the channel weight. η is the effectiveness of the channel prediction. $\gamma,\beta\subseteq[0,1]$. The effectiveness of the prediction is reflected by the difference between the channel prediction and channel evaluation. The more accurate prediction is, the larger credibility of the prediction for the channel weights is, that is to say, the greater η are. So:

$$\eta=1-\frac{|Q_i'(t)-Q_i(t)|}{\sum_{i=0}^{n}|Q_i'(t)-Q_i(t)|} \tag{15}$$

Furthermore, in order to better reflect the degree of the tendency of the optimal channel for each channel within the valid range, we define:

$$\varphi(x_i)=\frac{x_i}{\sum_{i=0}^{n}x_i} \tag{16}$$

Then：

$$\varphi[Q_i(t)]=\frac{Q_i(t)}{\sum_{i=0}^{n}Q_i(t)} \tag{17}$$

$$\varphi[Q_i'(t+1)]=\frac{Q_i'(t+1)}{\sum_{i=0}^{n}Q_i'(t+1)} \tag{18}$$

So：

$$f(t+1)=f_0+\sum_{i=0}^{n}f_i\left[\frac{Q_i(t)}{\sum_{i=0}^{n}Q_i(t)}\gamma+\frac{Q_i'(t+1)}{\sum_{i=0}^{n}Q_i'(t+1)}(1\text{-}\gamma)\eta\right] \tag{19}$$

6. The Simulation and the Analysis

The analysis of delay and loss rate of the channel is used to evaluate the proposed scheme. In this article, we do a simulation to our model by using NS2 simulation software. At first, we got an out.nam and an out.tr after running our tcl file. Then we can analyze our out.tr by delay.awk and drop.awk. The last step, we show the simulation results in the form of graphs.

6.1. Transmission Delay

Figure 2 shows that the changes of the channel transmission delay. We take a data once a second. It can be seen from the simulation that the system has been interfered from 20 seconds with the transmission delay increasing obviously. The transmission delay returns to normal after hopping to optimal channel, through the scheme. The result can prove the validity of our model.

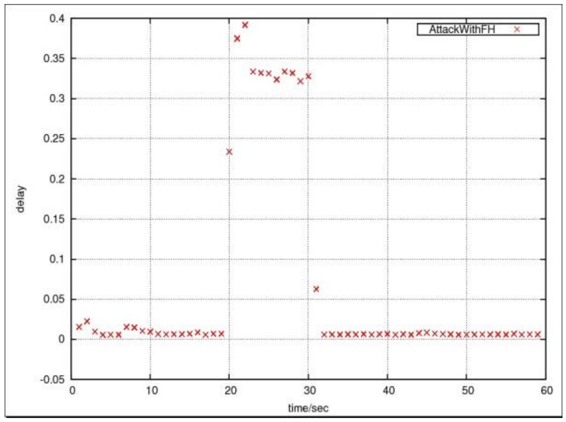

Figure 2. The Analysis of Delay

6.2. Loss Rate

Figure 3 shows that the changes of the channel loss rate. We can see from the chart that we take a data once a second as well. When the network is disturbed, the loss rate increases significantly, even up to 0.28., The loss rate returns to normal after skipping to the optimal channel through the scheme. When the loss rate returns to zero, it indicates the system becomes normal and proves the effectiveness of this scheme.

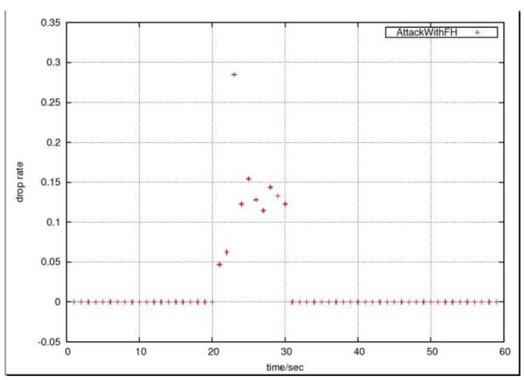

Figure 3. The Analysis of Loss Rate

7. Conclusion

In this paper, we do the research on the SNR, transmission delay and the loss rate of the channel, and proposed a reasonable channel evaluation method. The main contribution of this paper include: (1) Proposed a reasonable channel evaluation method, which considers the SNR, the transmission delay and the loss rate of the channel, making the channel evaluation more comprehensive; (2) Proposed the concept of accuracy of the channel prediction, which is reflected by the difference between the channel prediction and the channel actual evaluation, combining with its weight to make the optimal channel selection more reasonable; (3) Proposed a more reasonable method of optimal channel selection, which is obtained by combining channel evaluation and channel prediction, to make the selection of the optimal channel more reasonable.

Acknowledgments

This work was supported by "Funding Project for Academic Human Resources Development in Institutions of Higher Learning under the Jurisdiction of Beijing Municipality (PHR201007121)", "Beijing Natural Science Foundation（4132026）" and "2012 Youth key Foundation of North China University of technology". The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

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